REMARKS/ARGUMENTS

Interview

The Applicant thanks the Examiner for the opportunity to conduct a telephone interview on 22 February 2010 to discuss the application and cited prior art. The applicant confirms receipt of the interview summary mailed February 25, 2010, and comments on the substance of the interview as follows.

The Applicant notes that only the applicant's representatives Timothy J. Sinnott and Stanley K. Khaing of Bereskin & Parr LLP and Examiner Merouan participated in the telephone interview.

During the interview, the applicant's representatives explained claim 1 of the application based on the Specification and the drawings. The applicant's representative also discussed the indexing system disclosed by U.S. Patent No. 4,809,202 issued to Wolfram and NPL entitled "Geodesic Discrete Global Grid Systems" by Sahr *et al.* In particular, the applicant submitted that neither Wolfram nor Sahr does not teach an indexing of the cells as claimed in claim 1 of the subject application.

No agreement was reached between the Examiner and the Applicant at the telephone interview.

Office Action

This Amendment is responsive to the Office Action dated November 25, 2009. Claims 1- 49 remain in the application. Claims 1, 7, 13, 22 - 25, and 36 have been amended. New claims 50 and 51 that are dependent on claim 1 have been added.

Claim Rejections - 35 U.S.C. §103

In the Office Action, the Examiner rejected the claims 1-5, 7-11, 14-25, 27-29, and 41-49 under 35 U.S.C. §103 as being unpatentable over U.S. Patent No. 4,809,202

by Wolfram (hereinafter "Wolfram") in view of NPL Kevin Sahr *et al.* "Geodesic Discrete Global Grid Systems", Cartography and Geographic Information Science, Vol. 30, No. 2, April 2003, pp. 121-134 (hereinafter "Sahr").

Claim 1

As discussed in the telephone interview with the Examiner, claim 1 defines a method for storing two-dimensional spatially organized data in one dimensional space on a computer storage medium. In particular, the method includes the step of uniquely identifying each cell with a sequential number that includes the identification number of a parent cell. Each of the parent cells at least partially encompasses a cluster of child cells in a spatial hierarchy. Relationships between each parent cell and one or more child cells are defined by the following two rules.

The first rule indicates that each parent cell whose centroid is not the centroid for any lower resolution cells defines a location of a single new child cell of a next highest resolution.

The second rule indicates that each parent cell whose centroid is also the centroid for any lower resolution cells defines a location of multiple new child cells of the next highest resolution including one new child cell at the centroid of the parent cell and one new child cell located at each vertex of the parent's boundary edge.

Claim 1 has also been amended to add the limitation that mapping applies to multi-resolutional tessellation of close packed uniform aperture three hexagonal cells. Support for this amendment can be found at least in paragraphs [0067], [0141], Figures 4a - 4f, 5a - 5f, 6a, 8a, and 9c - 9e of the specification, and claim 13 as originally filed.

As stated in paragraph [0067] of the specification, "in an aperture three hexagon subdivision, at any given resolution "n", the area of a general hexagon is 3 times the area of a hexagon one resolution higher "n+1". Thus in the case of the claimed multi-

resolutional tessellation, the area of a parent hexagon cell is three times the area of the child hexagon cell. Multi-resolutional tessellations of close packed uniform aperture three hexagonal cells can be observed in Figures 4a - 4f, 5a - 5f, 6a, 8a, and 9c - 9e of the subject application.

As noted in Sahr, cells between adjacent resolutions of a DGGS (discrete global grid system) may or may not be congruent depending on how the cells are laid out. The Applicant notes that the method as claimed in claim 1 is directed to <u>incongruent</u> tessellations because the tessellations contains aperture three hexagonal cells. The aperture three hexagonal cells necessarily define incongruent multi-resolution tessellations as it is not possible to produce a congruent aperture three hexagon tessellation.

As defined in Sahr, a DGGS is "*congruent* if and only if each resolution *k* cell region consists of a union of resolution *k+1* cell regions". (Sahr at pg. 122, left column) Accordingly, A DGGS is incongruent if the region of one or more child cells (i.e. a cell in k+1) overlaps the boundaries of more than one parent cells (i.e. cells in resolution k).

For example, if a plane is divided into aperture 3 hexagons as shown in Figures 5b and 5c of the subject application, the region of some child cells overlaps a number of parent cells. That is, the region covered by child cell 773 shown in Figure 5c overlaps the region covered by parent cells 73, 74, and 77 shown in Figure 5b. In such situations, to maintain the unique hierarchical index including the identification of the parent cell, it is necessary to define exactly one parent cell to that child cell. The two rules stated above organize the parent-child relationship to resolve this issue.

The first rule defines the scenario where a parent cell has only one child. Using Figures 5a and 5b as examples, this rules apply to cells 71 – 76 in Figure 5b, since the center of these cells are not center of any lower resolution cells. That is, the

location of the center of cell 73 in Figure 5b is not the same as the location of the center of cell 7 in Figure 5a. In such situations, each cell has exactly one child. As shown in Figure 5c, the cells 71, 72, 73, 74, 75, and 76 each has only one child, namely cells 717, 727, 737, 747, 757, and 767 respectively.

The second rule defines the scenario wherein a parent cell has multiple children. For example, cell 77 of Figure 5b has a centroid that is the centroid of a lower resolution cell. That is, the location of the center of cell 77 is the same as the location of the center of cell 7 shown in Figure 5a. In such situations, the cell 77 has multiple children: one child at the centroid 770, and six children at the vertices 771, 772, 773, 774, 775, and 776 as shown in Figure 5c. The underlined portion of the index indicates the portion of the index that is the identification of the parent cell, namely "77".

Assigning hierarchical indexes to cells in accordance with claim 1 entails certain benefits. For example, since the index of each cell includes the parent's identity, it is possible to identify the cell's parent, other cells of the same parent (if any), and even the cell's parent's linage just from the index. For example, to determine a cell's grandparent, one would simply have to retrieve the identity of the cell's parent since the identity of the parent cell contains the identity of its (the parent cell's) parent.

Another advantage of the index is that it allows users to handle most probable queries efficiently by taking advantage of the hierarchical structural of the dimensions in spatial data (para. [0087]). Since a typical DGGS query is concerned with the cells from a common ancestor, assigning the cells of the same ancestor indices close to each other may reduce memory seek/search time, and rotation delay on some hard drives. There is also a procedure for determining whether a point as spatially contained, overlapping or excluded from a specific cell using Boolean algebra (para. [0089]).

The advantages described above should not be considered as an exhaustive list as there are other advantages to assigning hierarchical indexes to cells in accordance claim 1 as described in the Specification.

As described above, the method as claimed in claim 1 permits hierarchical indexing of multiresolutional incongruent hexagonal cells that entails certain advantages. The applicant submits that neither Wolfram not Sahr teaches the invention as claimed.

<u>Wolfram</u>

As discussed in the interview, Wolfram is directed at a method and apparatus for using cellular automata to simulate systems described by partial differential equations. According to Wolfram, a two dimensional space is tessellated into a cellular array of regular hexagons (Wolfram, Figure 1 and Column 4, Lines 15 - 17). Wolfram tracks the inflow of fluid (or diffusion or heat transfer) in each cell by tracking which of the six sides of the cell permits inflow of fluids from neighboring cells, for example by using a 6-digit binary number with each of the digits representing flow from a side of a hexagonal cell (Wolfram, Column 4, Lines 36-45). Wolfram provides a truth-table for each cell containing a series of rules to predict the outflow for any given inflow. (Wolfram, Column 4, Lines 49-69 to Column 5, Lines 1-6, and Table 1).

The cellular model defined in Wolfram contains only one resolution of cell tessellations. In other words, it is only two-dimensional and has only one "layer" of cells. The cells in Wolfram are represented in computer memory using a two dimensional array data structure. In particular, the memory addresses are assigned consecutive number order in a raster pattern starting with the cell in the upper left hand corner of the two dimensional space. (Wolfram, Column 8, Lines 43-65 and Table II).

In contrast, the cellular model claimed in the present application has more than one cell tessellation resolution or layer, and each layer may contain a different amount of

hexagonal cells than other layers (see for e.g. Figure 6). Each individual cells in each individual layer and relationship between cells in different resolutions need to be tracked and represented in a computer memory space. This can be contrasted with the model in Wolfram where there is only one resolution of tessellation of cells.

<u>Sahr</u>

Sahr discusses and summarizes a number of design choices for partitioning the Earth surface, including icosahedron for a base polyhedron and hexagon shaped cells for partitions. However, Sahr does not provide specific implementation details. In particular, it does not disclose defining parent-child relationship according the two rules and assigning hierarchical indexes based on that relationship as claimed in the present application.

In the Office Action, the Examiner cited the following paragraph in Sahr as the reason as to why the indexing is obvious in view of cited art.

> "Kimerling et al. (1999) and Clarke (2002) note the importance of regular ***hierarchical relationships*** between DGGS resolutions in creating efficient data structures. Two types of hierarchical relationships are common. A DGGS is congruent if and only if each resolution k cell region consists of a union of resolution k+1 cell regions. A DGGS is aligned if and only if each resolution k cell point is also a cell point in resolution k+1. If a DGGS does not have these properties, the system is defined as incongruent or unaligned. For example, the most widely used DGGS is generated implicitly by multiple precisions of decimal geographic vector representations. This DGGS has an aperture of 10 is incongruent and aligned (Figure 1)." (Sahr at Page 22 left column, emphasis added by the Examiner)

The Applicant submits that noting the importance of regular hierarchical relationships does not amount to method to defining parent-child relationships and indexing specifically as claimed in claim 1. The Applicant submits that this statement amounts to identifying a <u>problem to be solved</u>, namely a need for data structure that maintains hierarchical relationships.

The Applicant further submits that the solution to the problem as claimed is not a solution that would have been obvious to a person skilled in the art once the

problem is identified. There are more than one possible solutions to track hierarchical relationships. For example, cells in each resolution can be assigned serial index values, and the hierarchical relationship between different resolutions tracked using multiple look-up tables tracking the parent-child relationships. This indexing, however, is not as elegant or effective as the indexing as claimed.

The Applicant also submits that the solution as claimed fulfills a long felt need within the DGGS community as evidenced by the following commentary. Even within the same reference relied on by the Examiner (Sahr), the authors indicated under the heading "Direction for Further Research" that a "significant effort must be made by the data structures community to develop and evaluate algorithms for the regular but non-tree, hierarchies they (hexagon-based Geodesic DGGSs) form". (Sahr, page 133, left column, emphasis added) This suggests that there remains a need for efficient data structures and algorithms to manage hexagon-based Geodesic DGGSs at the time Sahr was published.

A challenge to develop an efficient data structure for hexagon cells is an ongoing challenge in the DGGS community even prior to publication of the Sahr article. In 1998, a publication by Carr et al entitled "ISEA Discrete Global Grid" (Statistical Computing and Graphics Newsletter, 1998, Vol 8, No 2/3, p31-39) stated that:

> "When the grid involves billions of cells, the indexing based on the rectangle bounding the foldable icosahedron planar view may be too wasteful. A first challenge is to develop a more efficient indexing system. Quite possibly this will just cover the twenty triangles with hexagons and handle the cells that cross the edges of touching Triangles ... Perhaps the most crucial task is to provide fast, conceptually acceptable algorithms for changing resolutions. As indicated earlier, lack of strictly nested cells at different resolutions poses a problem. The equal area projection approach easily adapts to strictly nested triangles, but that would give up some of the merits of hexagon cells." (*ibid.* at page 38, emphasis added)

In May 2002, Dr. Jon Kimerling (the same "Kimerling" that is cited by Sahr above) stated in a guest lecture at University of California, Santa Barbara noted the difficulty in addressing equal area projection involving hexagon cells as follows:

> Equal area map projection almost perfect hexagons, equal in area going finer and finer in resolution ... Divide Earth into basic geometric figure, projecting it w/equal area projection and then subdividing from there... One challenge is how to address the cells, which cell is next to which. (GEO 580 Guest Lecture on Alternative Data Structures, Discrete Global Grids, Dr. J. Kimerling 5/8/02, available: http://dusk2.geo.orst.edu/buffgis/dr_k.html, last accessed March 12, 2010, at page 2 near the bottom of the page, emphasis added)

In view of the above commentary, the Applicant submits that development of an efficient indexing system for incongruent tessellations of hexagonal cells was a long-felt need within the DGGS community. As such, the Applicant's invention as claimed could not have been characterized as being obvious to one skilled in the art at the material time.

The Applicant also submits that Wolfram and Sahr are directed to different fields of arts, and that it would not have been obvious to combine the two references. In particular, Wolfram is directed to two-dimensional simulation of flow of heat, liquid, or other transient entity while the Sahr reference is directed within the field of cartography.

The Applicant further submits that even if one were to combine the teachings of the Wolfram and Sahr reference, the combination will not amount to the method as claimed in claim 1, since neither references teaches or suggests the rules for determining relationships between parent and child cells, set out in claim 1.

In view of the foregoing remarks, the Applicant submits that the invention as claimed in claim 1 is patentable over the cited art and in condition for allowance. The Examiner is kindly requested to withdraw his objections to the same.

Claim 7

The Applicant has amended claim 7 to add limitations that the system memory comprises aperture three hexagonal cells, and parent-child relationship being determined using the rules similar to claim 1. The applicant submits that claim 7 is

now patentable over the cited art for the same reasons that claim 1 is patentable over the cited art. The Examiner is kindly requested to withdraw his objections to claim 7.

Claim 22

The Applicant has amended claim 22 to improve clarity of the language to better define the scope of the claim. Claim 22 has also been amended to add the limitation that the hierarchical series of tessellations are of uniform aperture three hexagonal cells.

Claim 22 recites the rules from the perspective of the child cell, while claim 1 recites the rules from the perspective of the parent cell. Claim 22 is similar in scope in comparison to claim 1. However, the Applicant notes that by amending the word "sequence" to "value", a sequential identifier need not be used to come within the ambit of claim 22.

Claim 22 defines a method of storing two-dimensional data. The method comprises defining a hierarchical series of multiresolutional tessellations of uniform aperture three hexagonal cells (Claim 22, para. (a)).

The method comprises assigning a unique index for each cell in each tessellation. For cells that are of the lowest tessellation resolution, in other words, the cells that do not have any parents are each assigned an index value that uniquely identifies that cell (Claim 22, para. (c)). Claim 22, para. (c) has been amended to clarify that cells in the lowest resolution are assigned unique index comprising an identifying "value" rather than a sequence.

For each cell that is not in the tessellation of the lowest resolution, that cell is assigned a unique hierarchical index comprising an index of a parent cell and an identifying value (Claim 22, para. (d)). The assigned index contains the identity of the parent in the form of the parent's index. Claim 22, para. (d) has been amended

to include the term "hierarchical" to describe the index. Claim 22, para. (d), and dependent claim 23 have also been amended to replace the term "identifying sequence" with the term "identifying value".

Parent-child relationships between the cells of higher resolution and lower resolution are defined by two "if ... then" rules in the claim.

The first rule states that if the center of a cell is located in the same place as the center of a cell in the next lower resolution, the cell in the lower resolution is the parent of that cell.

The second rule considers the case where the center of a cell is located at one of the vertex points of one or more cells in a lower resolution. Since it is possible that two or more cells in the lower resolution share the vertex point, each of the two or more cells is eligible to be the parent of that cell. However, since it is desirable for each child cell to have only one parent cell in its index, the method refers to a tessellation of one even lower resolution than the eligible cells (two lower resolutions from the child cell on a "grandparent" level) to determine the parent of the cell. The parent cell of the child cell is the eligible cell whose centroid location is the same as a centroid location of a cell in the even lower resolution tessellation.

The Applicant submits that claim 22 as amended is patentable over the cited art for the reasons provided above for claim 1. As such, the Examiner is requested to withdraw his objections to claim 22.

Claim 36

Claim 36 is directed to a system embodiment of claim 22. The Applicant has amended claim 36 to mirror the amendments in claim 22. The Applicant submits that claim 36 is now in a condition for allowance, for the same reasons provided above for claim 1.

New Claims 50 and 51

A new claim 50, which depends on claim 1 has been added by this amendment. The dependent claim 50 defines how the cells of each tessellation may be laid onto the faces of an icosahedron and projecting the data from the faces of the icosahedron to a geodesic spheroid. Claim 50 is supported at least by Figures 9a – 9e, and paragraphs [0140] – [0145].

A new claim 51, which depends on claim 1 has also been added by this amendment. Claim 51 limits the shape and orientation of the cells in claim 1 to conform to Icosahedron Snyder Equal Area Aperture 3 hexagon grid. Support for claim 51 can be found at least in Figure 9e, para. [0143] and claim 13 as originally filed.

Claims 50 and 51 are directed to applying method 1 to earth's surface. They indicate how the method as claimed in claim 1 may be applied to a DGGS. The Applicant submits that the claims 50 and 51 add further limitations to claim 1 and should be allowable for at least the same reasons that claim 1 is allowable.

Claims 13, and 23 – 25

Claim 13 has been amended to be dependent on claim 1. Claims 23, 24 and 25 have been amended to be dependent on claim 22. The Applicant submits that these claims are allowable for at least the same reasons that the independent claims are allowable.

Remaining Dependent Claims

Claims 2-6, 8-12, 14-21, 26-35, and 37-49 are directly or indirectly dependent on one of independent claims 1, 7, 22 or 36. The Applicant submits that these claims are allowable for at least the same reasons that the independent claims are allowable.

Conclusion

The Applicant submits that the above amendments and submissions overcome all of the Examiner's objections, and that each of the claims 1 - 51 is now in condition allowance.

The Applicant therefore respectfully solicits a Notice of Allowance.

Respectfully submitted,

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